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CO_2 emission mitigation and fossil fuel markets: Dynamic and international aspects of climate policies

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A B S T R A C T

This paper explores a multi-model scenario ensemble to assess the impacts of idealized and non-idealized climate change stabilization policies on fossil fuel markets. Under idealized conditions climate policies significantly reduce coal use in the short- and long-term. Reductions in oil and gas use are much smaller, particularly until 2030, but revenues decrease much more because oil and gas prices are higher than coal prices. A first deviation from optimal transition pathways is delayed action that relaxes global emission targets until 2030 in accordance with the Copenhagen pledges. Fossil fuel markets revert back to the no-policy case: though coal use increases strongest, revenue gains are higher for oil and gas. To balance the carbon budget over the 21st century, the long-term reallocation of fossil fuels is significantly larger—twice and more—than the short-term distortion. This amplifying effect results from coal lock-in and inter-fuel substitution effects to balance the full-century carbon budget. The second deviation from the optimal transition pathway relaxes the global participation assumption. The result here is less clear-cut across models, as we find carbon leakage effects ranging from positive to negative because trade and substitution patterns of coal, oil, and gas differ across models. In summary, distortions of fossil fuel markets resulting from relaxed short-term global emission targets are more important and less uncertain than the issue of carbon leakage from early mover action.

1. Introduction

Climate change and fossil fuel markets are interrelated. The use of fossil fuels contributes to the lion's share of greenhouse gases (GHG) emissions, in particular CO_2 [1]. Correspondingly, efforts to abate GHG emissions to mitigate climate change will likely affect global fossil fuel markets [2]. The response of fossil fuel markets to mitigation efforts will have an important influence on the costs and acceptability of abatement options [3]. The Intergovernmental Panel on Climate Change (IPCC) highlighted this crucial relationship some years ago [4,5]. Since then research and modeling of fossil fuel markets in

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Table 1
Description of scenarios developed in the two modeling set-ups of the paper.

Modeling set-up	Scenario description	Acronym in figures
(1) Global timing of mitigation	Baseline without restrictions on emissions	NoPol
	Stabilization with full 'when'-flexibility	550-e and 450-e
	Stabilization with low global emission target until 2030; 44.2GtCO2/yr in 2030 for fossil fuel and industry only and 46.6GtCO2/yr if land-use change emissions are included	550-Lo and 450-Lo
	Stabilization with high global emission target until 2030 37.3GtCO2/yr in 2030 for fossil fuel and industry only and 39.3GtCO2/yr if land-use change emissions are included	550-Hi and 450-Hi
(2) Fragmented participation	Fragmented policy baseline implementing regional Copenhagen pledges by regional carbon taxes	FragPol
	EU implements Road-Map on top of fragmented policy baseline	EU Road-Map
	EU and China implement uniform carbon tax from 450 ppm-e case on top of fragmented policy baseline	EU&CHN tax

state-of-the-art energy and integrated assessment models has improved considerably. Based on these advances, this paper seeks to assess the potential effects on fossil fuel markets induced by climate mitigation policies. A multi-model framework is used to understand these effects.

Policies aimed at long-term climate change stabilization are currently being debated in the political and scientific arena. Research so far focused on cost-optimal scenarios that are implemented by idealized policies—i.e., if no constraints on countries' participation and on the timing of action are imposed so that both 'when'- and 'where'-flexibility of emission reductions can be exploited to the largest degree. The international political process, however, has to date failed to negotiate a global, long-term climate change mitigation agreement. Therefore, more recent scenario studies, such as the AMPERE project, analyze deviations from idealized policies. In this context, the present study looks at the implications for fossil fuel markets.

The first deviation from idealized policy scenarios considers global, short-term emission targets derived by current voluntary pledges on the part of individual countries (see Table 1 for a general description). We study the implications of these short-term targets for achieving long-term levels of climate change stabilization, e.g., the 2 °C target. The dilemma we attempt to approximate with this model set-up is on the one hand the Copenhagen Accord that mentions the 2 °C target as a long-term stabilization objective, and on the other hand the short-term pledges actually agreed upon within the Copenhagen Accord (and later re-confirmed in the Cancun Agreement) that appear less ambitious and could make it difficult—if not impossible—to achieve the long-term target. There exist considerable uncertainties regarding the interpretation of some of these pledges (e.g. [6]). Therefore, in this study we include two alternative short-term emission trajectories until 2030 based on two distinct interpretations of the Copenhagen pledges about global near-term emissions: one high trajectory and one low trajectory, which reflect the uncertainty related to the formulation of the pledges. We analyze the implications of these short-term targets on long-term (until 2100) stabilization goals in the form of a stringent 450 ppm CO_2-eq and a less stringent 550 ppm CO_2-eq stabilization target.

The set-up of our experiment extends the scientific literature looking at the timing of carbon emissions and the resulting mitigation costs [7–12]. However, in contrast to this literature, we develop scenarios that are more in line with real-world policies, and we focus on the inter-temporal re-allocation of fossil fuel use and the resulting impact on fossil fuel revenues. The analysis focuses on the heterogeneity of fossil fuel uses and the inertia of energy sector infrastructure. These key factors determine fossil fuel market outcomes, which are interrelated in a complex way with the intertemporal re-allocation of carbon emissions that are consistent with the carbon budget. Other papers have looked at the fossil fuel markets implications of climate policy. For instance, [13,14] study fossil fuel use in idealized long-term stabilization scenarios, and [14] also tests the sensitivity of fossil fuel availability and changes of fossil fuel rents. Yet, none of these papers looks into short- and long-term implications of deviations from idealized 'when'-flexibility or the effect of more "realistic" policies.

The second deviation from idealized policies included in our scenario set-up (see Table 1) focuses on the effectiveness of early and unilateral mitigation policies in a fragmented climate policy world and assesses carbon leakage effects (for a broader overview see [15]). As a reference scenario we choose a world with fragmented emission mitigation policies. Because the focus shifts to the regional impacts of polices for this second part, we adopt country-specific Copenhagen pledges as well as specific technology policies. We then consider alterations of this reference case by assuming more stringent climate policies are undertaken in the EU and, in some of the scenarios, in China as well. We analyze the leakage and substitution of coal, oil and gas to explain the large range of carbon leakage.

Carbon leakage is frequently discussed because it has the potential to undermine the environmental effectiveness of unilateral climate policies. [5,16,17][1] argue that the 'industry channel'[2] and 'pollution haven' effects[3] are the main drivers of high carbon leakage effects. [18,19][4] highlight the relatively high importance of the energy market effects that work through re-allocation in fossil energy markets. A series

[1] [17] summarizes the results of the EMF29 model comparison study on carbon leakage.

[2] Production and goods trade are re-allocated so that an emission-constrained countries import goods with high carbon content, which offsets some of the domestic emission reductions. It is also known as competitiveness channel.

[3] Industries relocate from emission-constrained countries to unconstrained countries and therefore part of the emission reduction effort is offset.

[4] [19] relies on a single model framework and, hence, is different in nature to [17].